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The Light Clock Experiments and the Law of Reflection

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Elementary classical physics tells us that when a ray of light strikes a plane mirror, the light ray reflects off the mirror. According to the law of reflection, the angle of incidence equals the angle of reflection.

One of the most important results of Special relativity (SR) is the effect of time dilation [1]. This phenomenon has been demonstrated in many experiments, including the muon experiment [2] and the experiment of synchronizing two atomic clocks [3].

Many physics textbooks deal with the subject of time dilation. This phenomenon can be depicted using a device known as a light clock [4]. In this note, the relation between various light clock experiments and the law of reflection will be considered.

The light clock usually consists of two-plane parallel mirrors, M_1 and M_2, that face each other and are separated by a proper distance d, Fig. 1a. A light signal (or a photon) originating from mirror M_1 is reflected by mirror M_2 and finally returns to mirror $M_{1.}$ The light pulse traces out a path of length 2d. Of course, the angles of light signal incidence and reflection are equal to zero.

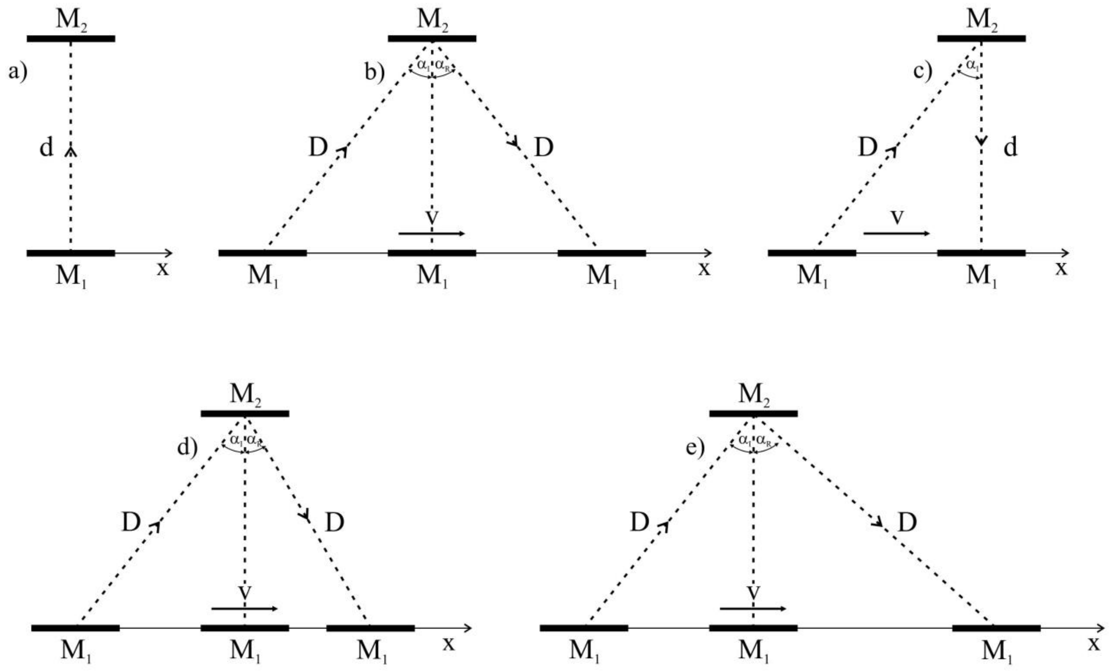

Fig. 1. Measurements and analysis for the light clock made in different frames.
(a): No relative motion; (b) – (e): the light clock moving at a speed υ, see the text.

Now, allow the same light clock to be moving with a certain relative speed υ horizontally in the direction of the positive x-axis. In this case, a stationary observer who is watching the light clock could design the following diagram, Fig. 1b. As previously, the light signal of mirror M_1 reaches mirror M_2 and reflects to mirror M_1. The light signal will now travel a larger distance 2D. The stationary observer concludes that this signal follows the law of reflection, i.e., the angle of light signal incidence (α_I) is equal to its angle of reflection (α_R), Fig. 1b.

Let us assume that the light clock makes a full stop when the light signal reaches mirror M_2. The stationary observer determines that the light signal angle of incidence α_I is greater than zero, but its angle of reflection α_R is zero degrees, Fig. 1c. Of course, this observation disagrees with the law of reflection. In addition, if we are dealing with a single photon as the light signal, any process of its detection at the mirror M_2 leads to its annihilation.

If the speed of the light clock after the light signal reaches mirror M_2 is lower than υ then the angle of reflection α_R will be smaller than the angle of incidence α_I, Fig. 1d. In the opposite case, if this speed is higher than υ the angle of incidence α_I will be lower than the angle of reflection α_R, Fig. 1e. Similar effects would be observed if the light signal after reaching mirror M_2 travels at a speed lower ("slow light") or higher ("fast light") than *c*, for some reason.

All these observations also disagree with the law of reflection. My friends-physicists argue that this disagreement is a result of changing from one inertial frame to another frame, though I am uneasy with this explanation. Indeed, SR states that "the speed *c* of light in a vacuum is the same in all inertial frames of reference in all directions and depends neither on the speed of the source nor on the speed of the observer” [5]. It sounds rather strange that the direction of motion of light depends on the inertial frame.

References

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